Diesel Power plants: Design and Operation and Performance Enhancement

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Abstract

Diesel power plants are widely used in stationary and mobile power applications ranging from emergency power plants, standby plants, peak power plants and black start plants. The main elements are an internal combustion engine and an electric generator for power generation. The main challenges facing diesel power generation are high greenhouse gas emissions, high cost of power and high fuel cost. Improvements on performance applied include use of supercharging, turbocharging, dual fuel conversion, and use of low carbon and renewable fuel sources in place of fossil fuels like biogas, biomethane, biofuels and natural gas.

Key Words: Diesel engines; Power generation; internal combustion engines; sustainable electricity

1.Introduction

Diesel electric power plants generally range from few 1 MW to 50 MW capacity or multiples of such based on installed capacity for power supply in central power stations, off grid stations, and are also universally applied to supplement hydro and thermal power plants as standby generators used for starting and emergency supply(Nag, 2008). Diesel power plants are generally installed in areas with no coal or natural gas supply with smaller and often discontinuous electricity demand like remote areas or off grid market or urban centers(Rajput 2021).

Many developing countries rely heavily on diesel power which accounts for both grid and off grid. This introduced the main challenges of high greenhouse gas emissions and extremely high electricity cost as customers pay for both energy and the fuel used in electricity generation besides other related direct and indirect costs(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022b). The technical challenges of diesel power generation include frequent breakdowns hence less reliability and power plant availability which attracts penalties in most power purchase agreements(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022d).

Continued reliance on fossil fuels and in particular diesel and heavy fuel oil for power generation is a leading source of high unit cost of power and growing greenhouse gas emissions(Kabeyi & Olanrewaju, 2021b; Kabeyi & Olanrewaju, 2021b). This high unit cost of power from diesel power plants is attributed to high cost of maintenance, high fuel costs, and engine related running costs like cot of lubrication which are high for typical of diesel engine power plant(Kabeyi & Olanrewaju, 2021a). Unlike renewable sources of power like solar, hydro power and geothermal, the consumers of power pay for both electricity used and the cost of fuel used in power plants. Additionally, frequent breakdowns experienced in many diesel power plants reduce the reliability of diesel power plants in supply of grid connected power(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022a 2022b) .

Diesel power plants are easy to design and install and they require lower capital costs. They can respond to load changes with ease and are easy to start and stop which makes them suitable for use as peak load power

plants. Diesel plants also have low stand-by losses, operate at high efficiencies of energy conversion from fuel to electricity and can be located near load centers(Rajput, 2021). These reasons make diesel power plants valuable and therefore despite the high-power costs associated with them, they cannot be completely done away with in some countries and applications. This necessitates a solution through development of a modern diesel plants that will aide in curbing the high electricity costs(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022e).
In this study, the design, construction and operation of diesel power plants is undertaken with a view of improvement performance and sustainability. Data was collected from literature survey of studies on the operation, maintenance and applications of diesel engine power plants.

2.Design, And Operation of Diesel Power Plants

Diesel power plants mainly use diesel or compression ignition engine as the prime movers. The diesel engine was named after Rudolf Diesel who invented it in 1898 by using the principle of compression ignition. The fuel used in these engines since then was also named diesel. Heavy fuels though, have been found to be more economical in the operation of diesel power plants over the last two to three decades. This chapter reviews all relevant literature on the diesel engine, being the key component in these plants, the criteria of measuring its performance, other components of the plant, developments that have been made to improve plant efficiency and the development of diesel power plants(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022f; Rajput 2021).

2.1. The Diesel Engine

In the diesel engine, fuel is injected into the engine cylinder by the fuel injection system towards the end of the compression stroke and just before the desired start of combustion. The fuel is injected at high velocity through small orifices at the injector tip. It atomizes into small droplets and penetrates the combustion chamber. On getting into the combustion chamber, the fuel vaporizes and mixes with the high-pressure high temperature air in the cylinder. Spontaneous ignition of the already mixed portions of fuel and air occurs, and the consequent compression of the unburned portion brings it to combustible limits causing rapid burning. The burning gases expand and do work on the crank(M. Kabeyi & O. Olanrewaju, 2022). Figure 1 demonstrates the construction of the diesel engine prime mover.

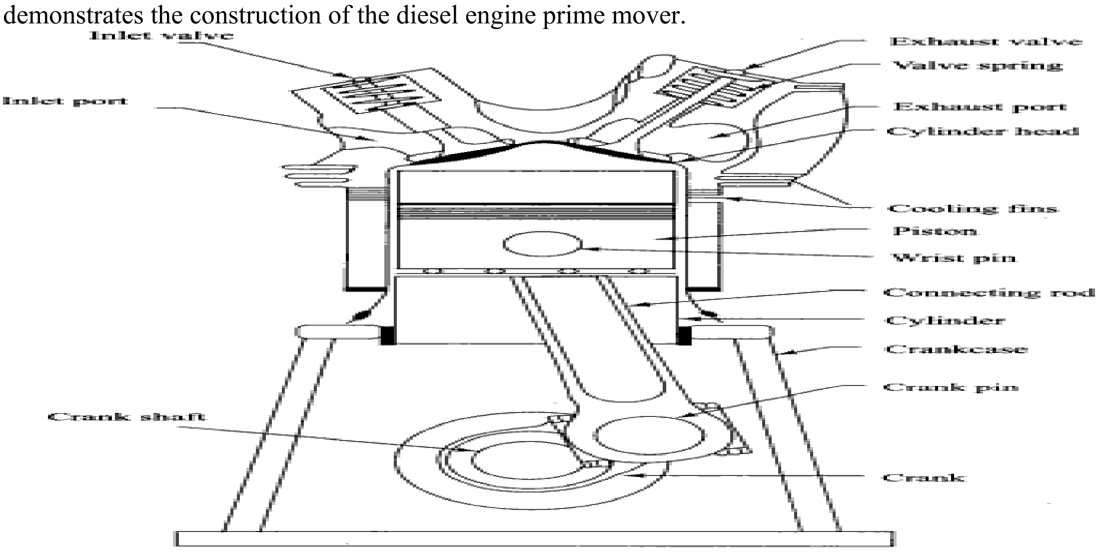

Figure 1. Reciprocating diesel engine

From figure 1, it is noted that the main elements of a diesel engine prime mover are the crank shaft, cylinder head, connecting rod, piston, the crank case, the cylinder, inlet and outlet valves among others.

3. Engine Performance Criteria

3.1. Brake Power

The engine is used to produce mechanical power by combustion of fuel. Power is defined as the rate of doing work. It is a product of torque and angular velocity. The engine is connected to a dynamometer which is loaded in a way that the torque exerted can be measured and the angular velocity is measured using a tachometer. The power developed by the engine, which can be measured at the output is referred to as brake power (Bp)(Nag 2008).

Bp= 2πNT/60

Where: T is the torque in Newton-meter (N-m), is the angular velocity in revolutions per minute (rpm) and Bp is the engine brake load measured by a dynamometer.

3.2. Indicated Power

This is the power developed by combustion of fuel in the engine cylinder. It is given by;

Ip= PLNn/60

Where: P is the mean pressure; L is the displacement volume of the piston or stroke length and n is the number of cylinders and N is engine revolution per minute(Nag, 2008).

3.3. Friction Power

This refers to the difference between indicated power and brake power. It represents all the losses of the engine.

F_P=Ip-Bp where F_p is fuel power which is a function of the calorific value of the fuel and B_p is brake power of the engine which is the engine mechanical output at the crankshaft end.

3.4. Mechanical Efficiency

It is given as the ratio of brake power to indicated power as a percentage.

η_M= Bp/Ip *100%

The relationship between mechanical efficienncy and brake power is shown in figure 2

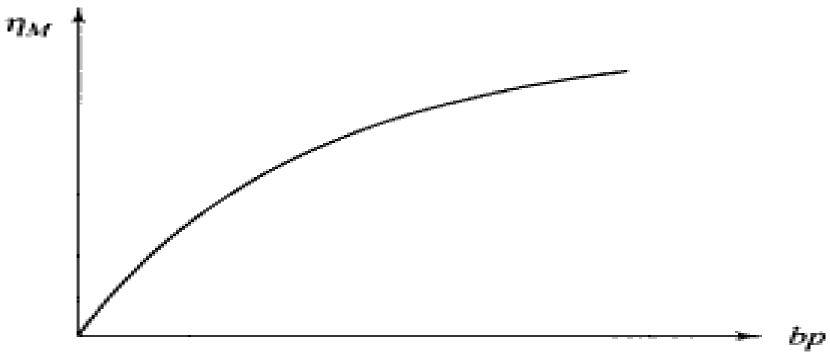

Figure 1. variation of mechanical efficiency with brake power

From figure 2, it is noted that the mechanical efficiency is directly proportional to the brake power. The efficiency growth rate however diminishes as the brake power increases which makes it necessary to identify optimal load and operating conditions.

3.5. Indicated Thermal Efficiency

This is the rate of indicated power to thermal input; η_i= Ip/fuel power where; Fuel power= m_{f*} C_v where m_f is mass flow rate and, Cv is fuel calorific value(Nag, 2008)

3.6. Brake Thermal Efficiency

This is the ratio of brake output to thermal input.

η_{Bp}= Bp/m_f* C_v

3.7. Specific Fuel Consumption

Specific fuel consumption is a measure of the fuel used to generate a kWh of power. It is given by the ratio of brake power to the product of mass flow rate and volume flow rate.

sfc= Bp/ $m_{f*}Q_{net}$

4. Plant Components and Layout

4.1. Layout of Components

The diesel engine power plant is an assemble of the diesel engine coupled to a generator and various auxiliary parts and systems. This is demonstrated in figure 3.

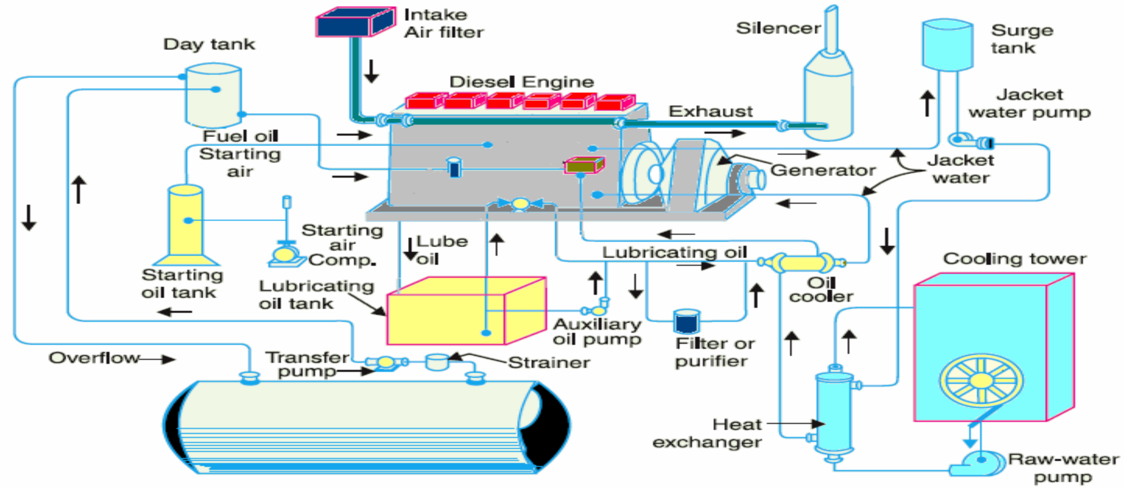

Figure 2. Components of a diesel power plant

From figure 3, it is observed that the main elements of a diesel power plant are the engine prime mover, the generator set for power generation, the lubrication oil and system, the cooling system, silencer, charge air system, etc.

4.2. Diesel Plant Components

i.) Diesel Engine

This is the main components of the power plant. It is directly coupled to the generator to develop power.

ii.) The Generator

Rotary motion from the engine is translated to the generator rotor. In presence of a magnetic field, this motion induces a magnetic flux generating an electric current thus converting mechanical energy to electrical energy(Nag, 2008).

iii.) Air Intake System

The air intake system delivers combustion air through louvers and air filters to remove dirt from incoming air. Dry air filter or oil bath air filter may be used to enhance filtration or air cleaning. The dry air filter consists of wool, felt or cloth while the oil bath filters the air is brushed over a bath of oil, so the dust particles are coated(Nag, 2008).

iv.) Exhaust System

The exhaust manifold connects the engine cylinder exhaust outlets to the exhaust pipe which is muffled to eliminate noise since the exhaust line is under high pressure. The exhaust pipe should have flexible tubing system to take up effects of expansion due to high temperature and isolate the exhaust system from engine vibration(Nag, 2008).

v.) Fuel System

The main elements of the fuel system include the fuel transfer pumps, fuel injection pumps, storage tank, heaters, and strainers. The fuel pump draws fuel from the storage tank and with the help of filter it is supplied into the day tank. The day tank is usually placed higher than the engine so that fuel flows into the engine by gravity. It supplies the daily fuel needed by the engine. The fuel is filtered again before it is injected into the engine with the help of fuel injector pump. The fuel injection system performs functions such as: filter the fuel, meter the correct quantity of fuel to be injected, time the injection process, regulate the fuel supply, secure fine atomization of the fuel oil and distribute the atomized fuel properly in the combustion chamber(Nag, 2008). The fuel system construction is demonstrated in figure 4

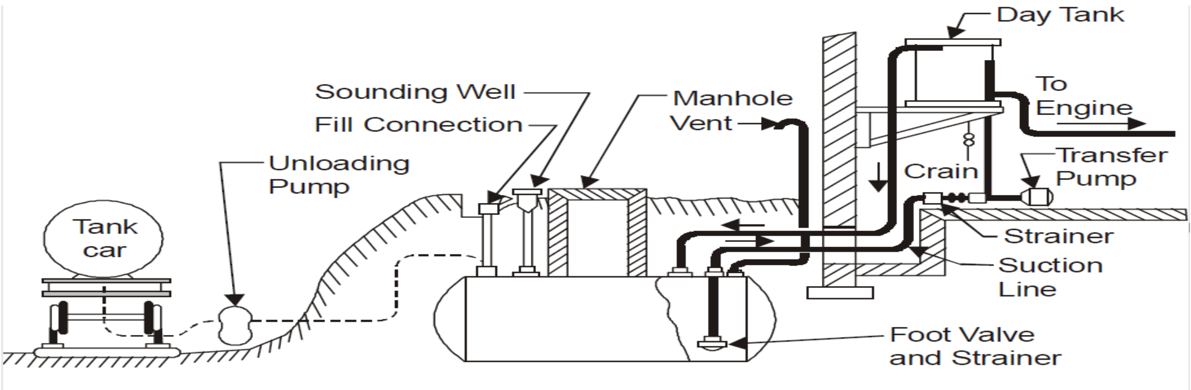

Figure 3- The fuel system

From figure 4, the main elements of the fuel system are identified as the unloading pump, fuel storage tank, the day tank, fuel transfer pump, fuel filters and fuel injector pump.

vi.) Cooling System
The engine needs cooling as the temperature of burning gases in the engine cylinder is very high (1500°c - 2000°c). To regulate this temperature, water is circulated in water jackets inside the engine. This water is then sent into the heat exchanger where raw water is supplied to take away its heat. The hot water is then sent to the cooling towers after which it recirculates. Cooling is necessary since, the lubricating oil used determines the maximum engine temperature above which the lubricant deteriorates rapidly and may evaporate and burn damaging the piston and cylinder surface. Also, high engine temperatures may result in very hot exhaust valve giving rise to pre-ignition and detonation or knocking. The strength of the materials used for various engine parts decrease with increased temperature inducing local thermal stresses due to uneven expansion resulting in cracking(Nag 2008).
vii.) Lubrication System

This includes oil tanks, coolers, pipes, and oil pumps. The main purpose of lubrication is to reduce friction, tear, and wear of the engine components. The lubricant forms a thin film between rubbing surfaces preventing metal-to-metal contact. After use hot oil is passed through chillers for cooling then reused.

viii.) Engine Starting System
There are three common methods of starting an engine which include: use of an auxiliary engine mounted close to the main engine that drives the latter through a clutch or gear, by use of an electric motor in which a storage battery is used to supply power to drive the engine and by use of compressed air supplied to a few engine cylinders making them work like reciprocating air motors to run the engine shaft. The compressed air system is commonly used for starting large diesel engines employed for stationary power plant service(Nag, 2008; Rajput 2021).

5. Technological Advances and Performance Enhancements

Since invention of the engine many efforts have been made to improve its efficiency. In diesel power plants, higher efficiency of the engine means better fuel economy since higher output can be obtained from the fuel. These advancements include artificially aspirating the engine to increase air intake and introducing engines that can use dual fuels. Means of using the exhaust heat have also been introduced to improve the fuel economy(Nag, 2008).

5.1. Supercharging

The purpose of supercharging is to raise the volumetric efficiency above that value which can be obtained by normal aspiration. It is desirable that an engine intake the greatest possible mass of air since ihp produced is directly proportional to air consumed. The supplied air is pumped into the cylinder at a pressure greater than atmospheric pressure and is called supercharging. It is used to increase the rated power output capacity or make the rating equal at high altitudes(Rajput, 2021).

Supercharging has numerous advantages including increased power output due to increased mean effective pressure (mep) better mixing of fuel and air reducing the specific fuel consumption thus it has good fuel economy, reduced knock due to increased compression ratios resulting in eased combustion. Also, there is increased mechanical efficiency due to increased power gain. However, supercharging has a few limitations such as unguaranteed maximum performance of the supercharger since they can consume up to 20 percent of the engine's total power and decreased reliability due to increased pressure(Nag, 2008; Rajput, 2021).

5.2. Turbocharging

A turbocharger is driven by a gas turbine using energy in exhaust gases. Heat exhaust is used to spin a turbine which drives a compressor. The compressor draws ambient air and compresses it. This boosts the intake manifold pressure and density to make the cylinders ingest more air during each intake stroke. This increases the power by a factor approximately 2 or 3.

There are several benefits of turbocharging such as high thermal efficiency, high speed, better fuel economy and it is eco-friendly. However, there are two major limitations that are difficult to overcome, increased engine weight and increased engine cost [6]. Figure 5 shows the engine charge air system with a turbocharger.

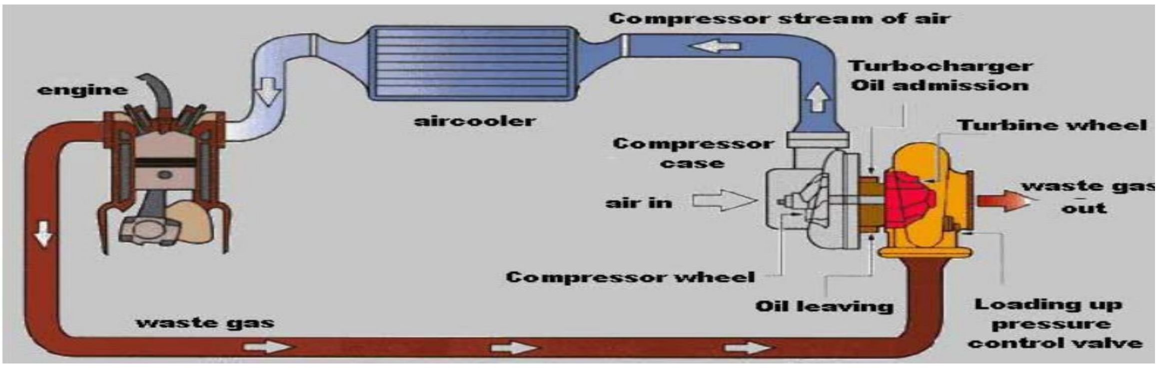

Figure 4- turbo charging

From figure 5, the main elements of the turbocharging system are the turbocharger turbine wheel, the air compressor wheel, exhaust gas piping to the turbine wheel, exhaust gas outlet from the turbine wheel, and air cooler for compressed gas from the turbocharger compressor.

5.3. Dual Fuel Engines

This is the phenomenon where the diesel engine is designed to run on two different fuels for instance the heavy fuel oil and natural gas. This concept was introduced by Rudolf Diesel himself during his research and development of the diesel engine. Rudolf introduced what is commonly known as pipeline natural gas into the air intake system. Due to high heavy fuel oil prices many countries are searching for an alternative to this conventional fuel. Emissions with dual fuel engines are also less and with the growing global concern on pollution they have become preferred(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022c).

In dual fuel engines, the primary diesel is used for ignition as the pilot ignition fuel for the combustion chamber mixture since compression ignition engines do not have spark plugs. The natural gas is then introduced. These engines therefore retain the fundamental principles of operation of diesel engines while allowing for use of cheaper and cleaner fuel(Rajput, 2021).

The gaseous fuel is admitted into the cylinder through fumigation or single point admission when the engine is a high-speed engine that is runs at speeds between 1200 and 1800 revolutions per minute. With this method fuel is admitted into the engines air intake system through mixers installed upstream of the turbocharger. The flow of this fuel is controlled using a butterfly-type throttle valve located before the mixer. This technique allows for substitution of fuel of between 50% and 70%.in low-speed engines that is those that run at speeds below 1000 revolutions per minute, the gaseous fuel is not admitted the same way. The fuel is injected at individual cylinders, and this is known as multi point injection(Kabeyi, 2012; Kabeyi & Olanrewaju, 2021b)

Dual fuel engines are cost effective since the use of expensive heavy fuel oil is regulated and the cheaper natural gas can be used. Retrofitting existing plants to dual fuel operation can be done without changing the core engine or the plant fuel management system. This cost can be recovered quickly upon retrofitting due to the improved fuel economy. With this conversion maintenance intervals and engine life are extended(Kabeyi, 2012; M. J. B. Kabeyi & a. O. Olanrewaju, 2022).

5.4. Cogeneration

Cogeneration or combined heat and power (CHP) is the phenomenon of generating two different forms of energy from a single primary source of energy. The two forms of energy are typically mechanical and thermal. The mechanical energy is used either to run a generator and produce electricity or run rotating equipment such as motors, compressors, fans or pumps. The thermal energy is used to produce steam, hot water, hot air for dryers or chilled water for process cooling. Cogeneration systems are classified into topping and bottoming cycles(Belyakov, 2019; Hegde, 2015). This is on basis of sequence of energy use. With the topping cycle, fuel is used to produce electricity first and then heat that is a by-product of the process is recovered and used. The bottoming cycle involves the production of high temperature thermal energy from the fuel and the rejected heat being used to produce electricity through a recovery boiler and a turbine generator(Kabeyi, 2018; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022b).

When cogeneration is applied in diesel power plants, the mechanical energy drives the generator to produce electricity while the thermal energy is used to heat water to produce steam that is used to run a steam turbine producing more power. This is referred to as a combined cycle topping system. In this process there are two sources of heat recovery; heat from the exhaust gas that is at high temperature and the engine jacket water cooling system that is at low temperature(Kabeyi & Olanrewaju, 2021b; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e).

Cogeneration helps generate more power from the same primary energy source bringing the cost of a unit of power down. The configuration of a diesel engine based cogeneration system is shown in figure 6 below.

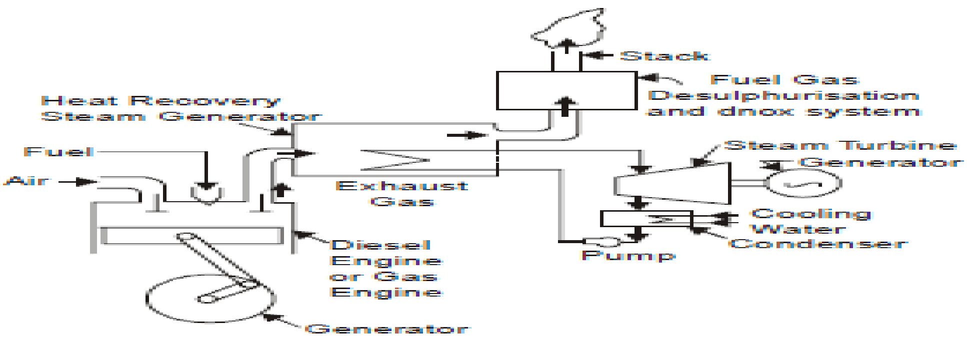

Figure 5- Engine based cogeneration system

From figure 6, it is observed that an engine based cogeneration system utilized exhaust leaving a diesel or gas engine to generate steam in a heat recovery steam generator. The exhausts are then emitted through the stack after excess heat recovery. Steam generated is used to run a steam turbine for extra power generation.

6.Application of Diesel Power Plants

Diesel power plants have been largely used for a long time around the world. They have particularly been used in the developing Asian and African countries for peak power supply as well as base load power supply. Diesel power plants are popular among developing countries since diesel power plants are easily used in micro power grids or nursery stations for remote areas not connected to the national grids. The infrastructure in these third world countries is not well developed thus a big need for the nursery stations. Diesel power plants have also been used to produce power for sectors like agriculture with a country like India estimated to have about four million small diesel engines to run irrigation pumps. Diesel power has been preferred in information technology (IT) and data centers since it is the most efficient backup system in the event of power failures to prevent data loss(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju, 2022; Kabeyi & Oludolapo, 2020e).

Diesel power plants are used as peak load power stations in combination with other plants. This is because they can be easily started and stopped based on varying electricity demand. In applications that require mobility of the power source, diesel stations are appropriate since they can be mounted on trailers and used at different locations. In cases of power shortfalls diesel plants can effectively be used as emergency plants. Diesel power plants can also be used as black starts to start main plants such as nuclear and coal plants. While diesel plants are used as stand-by units to supply the main plants they can also be used as main plants to supply the base load(Kabeyi, 2018; Kabeyi & Olanrewaju, 2021a; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e, 2022f).

Today diesel engine power plants are used in many developed countries as emergency and stand-by units while other power plants like nuclear, gas, coal, wind and solar are more widely used for base and peak load power supply. Countries with vast geothermal resources and hydro are shifting from over reliance on diesel power plants mainly due to concerns lover cost and environmental pollution. This is because of the high unit costs associated with diesel power and high greenhouse gas emissions(Kabeyi & Oludolapo, 2020c, 2020e).

7. Results and Discussion

Diesel is the main used in industrial, transport, and in diesel power plants and its demand is still growing(Arefin et al., 2020). Therefore the world has a dual need to reduce emissions and cost of power from diesel engine power plants to address sustainability in power generation (Niemi, 1997). Economically, reliance on diesel power especially during low rains contributes to high cost of grid electricity leading to high electricity bills (Andae, 2017). The environmental impact of diesel power plants includes emission of So_x and NO_X emissions e.g. SO_2 which undergoes chemical reactions with moisture in the atmosphere to form sulfuric acid (Barasa, 2020; Jeremiah, 2018). The emissions also react with the ozone layer leading to its depletion(Kabeyi & Oludolapo, 2021). The greenhouse gases are responsible for the global warming in addition to other health effects to humans like chronic respiratory diseases, lung cancer, heart diseases, and damage to brain, liver and kidneys(M. J. B. Kabeyi & A. O. Olanrewaju, 2020; Kabeyi & Oludolapo, 2020a, 2020d).

It costs KES6.00 to produce 1 kWh of electricity using natural gas (Eurostat, 2020) which is much lower compared to diesel power generation which costs about KES. 30 (Andae, 2017; Kabeyi & O. A. Olanrewaju, 2020) which implies that power from natural gas is about 5 times cheaper than power from diesel, although many other factors may influence the actual cost depending on the country. Therefore, conversion to natural gas will reduce the cost of power generation. Diesel generators (DG) are economically cheaper to purchase, but technically more y expensive to operate and maintain especially during partial load conditions which are less efficient as a result of high fuel cost delivered to the power plant from far away. Diesel engines also have many moving parts leading to high rates of failure and increased cost of operation and maintenance(Kabeyi, 2020; Kabeyi & Olanrewaju, 2021a; Kabeyi & Olanrewaju, 2021b). As a double coincidence, diesel fuel is often delivered to remote power station by tracks and rail powered by diesel engines. Since the price Thus, since the price of diesel fuel is very dependent on the of diesel is high, this further increases the cost of diesel power produced. On the contrary large scale gas supply is often delivered by gas pipelines which are cheaper to operate and maintain. For cites which can only be conveniently accessed by air instead of road or rail for fuel delivery, the of power is higher than that power produced in those accessible by boat or by land(Kabeyi & Olanrewaju, 2021b; Kabeyi & Oludolapo, 2020b).

As far as the environment is concerned, the diesel power plants have significant environmental impacts besides the power plants being non-optimal and expensive to operate and maintain. Operation of diesel engines contaminates local air and soil and emit significant amounts of greenhouse gases. Since the use of these diesel generators is not optimal and is additionally very expensive, there is growing need to identify alternative fuels and means of generation to reduce cost of generation and environmental impact of diesel power plants (Giaouris et al., 2015; Issa et al., 2019).

7.1. Applications of diesel power plants(Nag, 2008; Rajput, 2021)

Diesel power plants have several applications as grid and off grid power plants. The applications are summarized in table 1 below.

Table 1: Summary of applications of diesel power plants

	Application	Description	Remarks/justification
1	Peak load plants	Diesel power plants can be used in combination with base load stations like thermal, hydro and nuclear to supply short period high demand e.g. peak load for centralized systems	They are quick to start and stop and are expensive for use as base load stations
2	Mobile plants	Diesel plants can be installed on mobile systems like trailers for use non stationary applications e.g. ships, remote construction sites	They have high power density and can be containerized for small power supply
3	Standby units	Diesel stations can be installed parallel to main power plants for use whenever the main plant cannot operate e.g. during drought for hydro power plants	They have less standby losses and hence idle cost is not high.
4	Emergency plants	Vital installations like industries and hospitals need continuous supply of power to sustain operations and emergencies even when there is no grid/main supply	They have less standby losses has cheaper to operate and maintain and have higher overall efficiency .
5	Nursery station	They can supply power to small towns and load centers before the arrival of the main/central electricity grid	They are easy and cheaper to install and dismantle for relocation
6	Starting stations	They can be used to start the auxiliaries of main power plants during starting	They are easy to start and stop
7	Central stations	For small demand, diesel power plants can supply base load	Ideal for supply of low demand e.g. 1 to 10 MW

From table 1, it is noted that diesel power plants have applications ranging from standby units, emergency units, central stations and backup generators for variable renewable stations.

7.1. Advantages Benefits of Diesel Power Generation

The design and operational characteristics of diesel engine power plants gives them a competitive edge over others in certain aspects of power generation. The advantages of diesel power plants are listed in table 2 below

Table 2: Advantages of diesel power plants

	Advantages /benefits	Reasons/ Remarks
1	They are easy to design, install and commission	The technology has undergone tremendous design improvement for over a century
2	Readily available in the market in standard sizes	Diesel engine prime movers and generators are readily available in the market hence easy acquisition and deployment
3	Easily adapt to load changes	This increases power system reliability and availability
4	Have low standby losses	Makes them ideal as emergency and standby systems
5	Have less space requirements	Reduces cost, increases flexibility and applications
6	Easy and quick to start and stop	This makes them ideal choice for peak and emergency load applications
7	Have less cooling requirements	The engines have advanced internal cooling deigns. Can be located in areas with water scarcity
8	Low capital cost requirements	Technology is mature and manufacturers enjoy economies of scale. Affordable to developing countries and customers
9	Less human resource requirement for operation	The diesel engine power plants are simple with few processes hence less complex operational requirements and few manpower needs
10	High fuel to electricity conversion efficiency	Diesel engines have high fuel hence lower specific fuel consumption for a given generation
11	High part load efficiency	Can supply variable load
12	Less civil engineering works	With less civil engineering works, project delivery is faster and cheaper
13	Can be located near load centers	Diesel power plants can be located in cities and other load centers cutting down on transmission and distribution losses and costs

14	Have no ash handling challenges	This reduces pollution and operation costs
15	Simple and easy lubrication	Low operating speeds and simple design. Operation and maintenance made easier

Table 2 demonstrates that diesel power plants have numerous advantages over other power plants in various aspects of power generation including operational stability, space requirements, delivery period, operation and maintenance costs, fuel efficiency, initial cost. This makes them number one choice for many applications other than concerns over cost of fuel and power, and high emissions hence environmental impact.

7.2 Disadvantages/Limitations of Diesel Power Plants

The design and operational characteristics of diesel engine power plants leads to some limitations compared to other types of power plants. These limitations are summarized in table 3 below.

Table 3: Disadvantages of diesel power plants

	Disadvantage/limitation	Description /Remarks
1	Have cost of operation	The diesel engine power plant operations has limited range of operations hence less personnel and operation related expenses making them cost effective
2	High maintenance cost	With many parts in motion, wear and tear is high for diesel engines hence higher cost of maintenance
3	High fuel cost	The world prices of diesel and heavy fuel oil as well as lubrication oil is high
4	Have capacity limitation	Diesel engines have limitations to maximum size hence many units are needed for a bigger capacity causing duplication of parts and systems which is expensive.
5	Noise	The engine has many moving parties which cause noise and vibrations
6	Overload limitation	Diesel power plants cannot supply overloads continuously unlike steam turbines which can be overloaded as high as 25%. Limited overload supply capability reduces power plants flexibility and applications
7	High emissions	Conventional diesel engines use fossil fuels which have high greenhouse gas emissions
8	Limited life	The life of the diesel engines is small varying from 5 to 20 years compared to hydro, nuclear and even coal. The limited life increased depreciation rate and hence profitability of the power plants
9	High greenhouse gas emissions	Conventional diesel power plants use fossil fuels which have CO_2, SO_2 NOx, particulate emissions which have high negative impact to the environment

From table 3, it is noted that diesel power plants have a number of limitations like high levels of greenhouse gas emissions, high cost of fuel hence power, short life span and capacity or size limitations.

7.2. Performance Enhancement Measures

Various design and operational measures can be put in place to enhance the performance of diesel power plants in both grid and off grid applications. These measures are summarized in table 4 below.

Table 4: Performance improvement measures for diesel engine power plants

		Description	Benefits, improvements
1	Supercharging	A charge air compressor driven by engine power output is used to compress the charge air which increases engine power output.	Engine out and hence the power density is increased.
2	Turbocharging	Increases engine power output by increasing engine charge	More efficient than turbocharger as it uses waste exhaust energy
3	Cogeneration	Waste heat is used to generate steam to run a Rankine steam turbine for extra power generation	Generation increased and reduces specific fuel consumption and emissions intensity
4	Dual fuel power plants	A design in which a diesel engine prime mover can run on diesel or heavy fuel oil and another gas usually natural gas	Natural gas is cleaner and has more power density. Dual fuel engines have less environmental impact and lower cost of generated power

5	Use of renewable fuel	The diesel or heavy fuel oil is replaced with an alternative fuel like biomethane or biodiesel	To increase energy security by eliminating or reducing demand for fossil fuel and reduce greenhouse gas emission

From table 4, it is noted that measures like use of dual fuel design where diesel is used simultaneously with a cheaper or cleaner fuel like natural gas or biomethane, cogeneration where extra power is produced from steam generated in waste heat recovery boiler, turbocharging where the charge air compressor is driven by engine exhausts and use of biofuels and other renewable fuels to reduce emissions and hence sustainability of power generation by diesel engine power plants.

8. Conclusion

Diesel power plants have wide applications in power generation as emergency power plants, nursery plants, peak power plants, standby plants, black starts and other applications. The plants have a thermal efficiency of between 30 to 40%, generate high levels of greenhouse gas emissions and the electricity from diesel power plants has energy and fuel costs making it more expensive than many other power pants. The efficiency of the diesel power plants can be increased by developing cogeneration plants to use exhaust heat to generate steam for operation of a steam turbine to generate extra power. The fuel cost and emissions can be reduced by use of biofuels and natural gas which is a cleaner fuel or biomethane which is a renewable fuel. The engine power output can be increased by use turbochargers and superchargers to compress the charge air which effectively increase engine power output while emissions from diesel power plants can be reduced by use of cleaner fuels like biogas, biomethane, natural gas and biofuels.

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